Reynolds Smoke-Consuming
Brick Furnaces

By
William H. Bryan

A. W. WRIGHT.

SCIENTIFIC TESTS

OF THE

Reynolds Smoke-Consuming Brick Furnaces

MADE AT

The Omaha Water Company's Plant, at Florence, Neb.,
September 15th, 1894,

BY

WILLIAM H. BRYAN,
Consulting Engineer, of St. Louis, Mo.

1897:
American Publishing Co., Printers and Book-Binders,
Omaha, Neb.

THE

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Consulting Engineer,

OF ST. LOUIS, MISSOURI.

Simple, Effective, Durable.

As thorough Smoke Consumers with marvelous Steam-Producing Powers, by using the cheapest grades of coal, **THE REYNOLDS SMOKELESS FURNACES** are the cheapest and the best.

(No Model.) 2 Sheets—Sheet 1.

F. REYNOLDS.

SMOKE CONSUMING STEAM BOILER FURNACE.

No. 486,167. Patented Nov. 15, 1892.

Fig. 1.

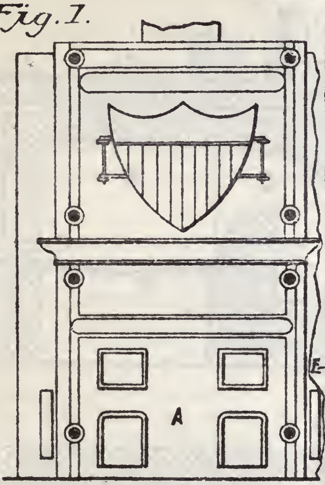

Fig. 2

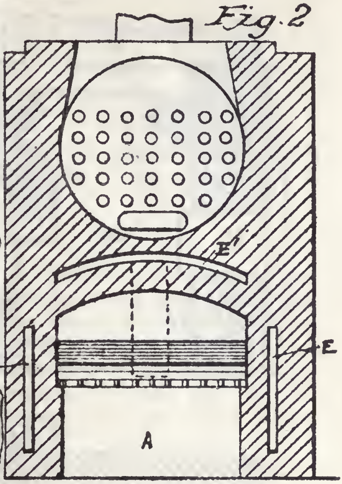

Fig. 3.

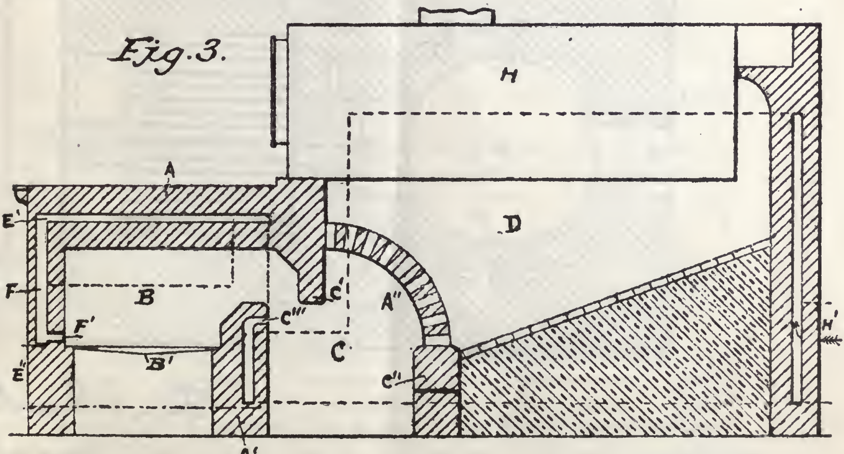

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Fig. 4.

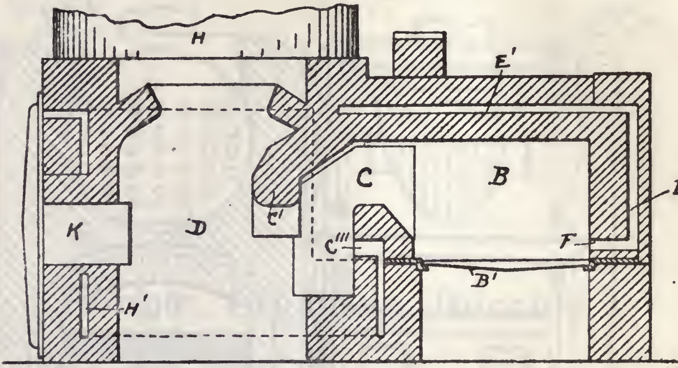
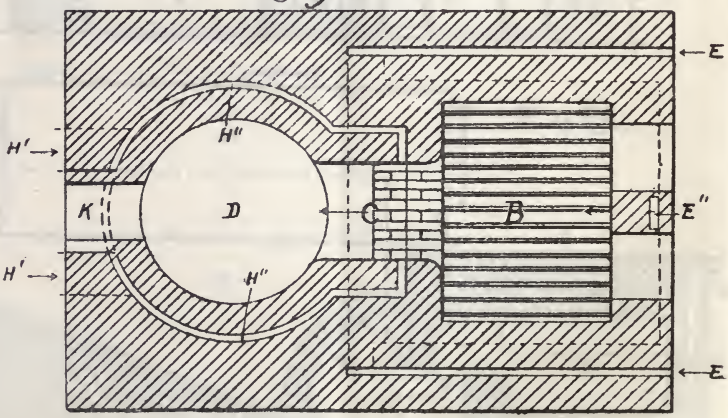


Fig. 5.



Frank Reynolds

Inventor

Witnesses
H. Weber
W. Donahoe

By his Attorney G. W. Sues

4—

DESCRIPTION

OF THE

Reynolds Furnaces

THE UNITED STATES PATENT OFFICE.

FRANK REYNOLDS, OF OMAHA, NEB., ASSIGNOR OF ONE-HALF TO ALONZO B. HUNT, OF SAME PLACE.

SPECIFICATION forming part of Letters Patent No. 486,167, dated November 15, 1892. Application filed August 29, 1891. Serial No. 404,151.

TO ALL WHOM IT MAY CONCERN:

Be it known that I, FRANK REYNOLDS, of Omaha, in the County of Douglas and State of Nebraska, have invented certain useful Improvements in Smoke-Consuming Steam-Boiler Furnaces; and I do hereby declare that the following is a full, clear and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, which form a part of this specification.

This invention has relation to new and novel smoke-consuming steam-boiler furnaces.

The object of this invention is to provide a steam-boiler furnace wherein the smoke may be consumed before leaving the furnace, as will be described more fully hereinafter, and finally pointed out in the claims.

In the accompanying drawings Figure 1 shows a front view of a horizontal steam-boiler furnace; Fig. 2, a transverse sectional view through the combustion-chamber; Fig. 3 shows a longitudinal section elevation; Fig. 4 shows sectional elevation of an upright furnace embodying my invention, and Fig. 5 a horizontal sectional view thereof.

Similar letters of reference refer to corresponding parts.

"A" represents a steam-boiler furnace of any suitable dimension, constructed of fire-brick or any other suitable material, comprising the combustion-chamber B, the intermediate chamber C, and the furnace D, as clearly shown in Figs. 3 and 4.

The combustion-chamber B is provided with the grate-bars B, and is in communication with the flue or intermediate chamber C. The walls of the chamber are built in two parts, so as to provide the air-pocket, as shown. This pocket comprises the independent vertical flues E E—one upon each side—and the top horizontal flue E', which communicates at the rear with two

side flues E E, descending in front by means of a narrow vertical flue F, leading into the combustion-chamber B, as shown by the outlet-opening marked F'. The rear wall A' within the chamber B terminates a suitable distance below the top of the chamber, so as to leave a contracted opening communicating with intermediate chamber C.

The intermediate chamber C forms properly a part of the main combustion-chamber D, and is provided at a point near the wall A' with a transverse, downwardly-extending, deflecting wall C', which ends approximately on a line with the wall A', as illustrated in Fig. 3. At the rear the intermediate chamber C is provided with an arch A'', having a suitable number of openings, which starts from the wall C'' and curves forward toward and against the wall C'.

The furnace D is of suitable masonry, within the upper portion of which rests the boiler H in communication at the rear with the furnace, as illustrated. The walls of the furnace are also provided with an interior air space or pocket running the full length of the wall until a point at the forward end where the space is contracted, so as to lead into the transverse wall A' and ending at the opening C''', leading into the chamber C, as shown in dotted lines in Fig. 3. The furnace is built so as to decrease in capacity as it nears the rear wall, so that the heat is focused or crowded before leaving or entering the boiler, as will be understood by referring to Fig. 3. The openings within the arch A'' offer a means of communication between the chamber C and the furnace D. At the rear I provide an opening H', covered by means of a suitable slide, so as to offer open-air communication with the chamber C. In Fig. 3 I have shown by means of an arrow the entrance of the air and at C''' its exit. In front I provide a slide-covered opening E'', by means of which the air enters the space surrounding the combustion-chamber, making its escape at the point marked F'.

All the masonry is of the best fire-brick, and when the furnace has been constructed according to my description the operation of my device is as follows: The heat from the burning fuel within the combustion-chamber passes first into the intermediate chamber C, and then through the openings within the arch A'' into the furnace D, escaping through the boiler into the chimney. As the combustion-chamber becomes warmer, the air within the wall space becomes expanded and heated and escapes into the fire-box or combustion-chamber, materially aiding the combustion. The air within the walls of the furnace escapes into the intermediate chamber C, intensifying the heat to such a degree that the smoke particles are practically consumed, the smoke passing off in vapors devoid of any floating particles, making the furnace a smoke-consuming device, and thus fulfilling the aim and object of this invention.

In Figs. 4 and 5 I have shown, respectively, a vertical sectional elevation and a transverse sectional view of my smoke-consuming furnace as arranged for a vertical boiler.

As in the arrangement of the horizontal device, I divide the furnace into the combustion-chamber B, the intermediate chamber C, and the furnace D, running to a focus at the upper end immediately below the boiler H.

In the arrangement of the furnace for the vertical boiler the curved wall is eliminated, the heat being directed against the depending wall C', and then entering directly into the furnace D. To facilitate cleaning the furnace, I provide the opening K, closed by means of a suitable door.

The operation is as in the preceding case—the air entering by means of the openings E, thence into the horizontal pocket E', down the vertical flue E'', and out at F, in the rear, entering at the opening marked H', circulating about the vertical way H, and out at C''', leading into the furnace, as shown in Figs. 4 and 5.

The device is exceedingly simple of construction, efficient, and readily operated. The air within the wall spaces or pockets is converted by the great heat into inflammable gases, and as such enter both the combustion-chamber and furnace, and thus assist in intensifying the heat, thereby raising it to such a degree that the floating products of combustion are disintegrated, leaving the chimney in the form of smokeless vapors.

It will be noticed that by my arrangement of the instrumentalities the heat in leaving the combustion-chamber is crowded or focused into a smaller chamber, into which there is a continued flow of combustible vapors. From this chamber the heat is permitted to enter the furnace of greater capacity than the intermediate chamber, the outlet of this furnace being again contracted, so that the heat is again crowded in leaving, as illustrated in the several figures.

Having thus described my invention and the best method I know of operating the same, what I claim as new, and desire to secure by United States Letters Patent, is—

1. In a boiler-furnace, the arrangement of a fuel-chamber provided with independent vertical flues upon the sides and communicating at the rear with a horizontal top flue and in front with a vertical flue leading into said fuel-chamber, the rear wall of said chamber terminating a suitable distance below the top, a communicating intermediate chamber of smaller capacity than said fuel-chamber and provided at a point near said rear wall with a transverse downwardly extending deflecting-wall and an arch having a number of openings leading into a furnace, and open-air flues surrounding said furnace and leading into said intermediate chamber, said furnace decreasing in capacity at the rear, so that the heat is focused or crowded before entering the boiler-flues, all substantially as and for the purpose set forth.

2. In a boiler-furnace, the combination of the fuel-chamber B, provided with the flues E E, E' and F, leading into said chamber, the wall A,' the chamber C, provided with the deflecting-wall C' and arch A'', walls C' and C'', and the furnace D, provided with an open-air pocket leading into the wall A' and escaping into the chamber C, all arranged so that the heat in leaving the fuel-chamber is focused into the smaller chamber C, and from this into the furnace D of greater capacity, the outlet of this furnace being contracted so that the heat is again focused in leaving, all substantially as and for the purpose set forth.

In testimony whereof I affix my signature in presence of two witnesses. FRANK REYNOLDS.

Witnesses:
G. W. SUES,
A. B. HUNT.

REYNOLDS SMOKE-CONSUMING STEAM-BOILER FURNACES

The following Report and Resolutions of the American National Association of Engineers appeared in the Omaha Daily Bee, Saturday, May 20th, 1893:

ENDORSED BY THE ENGINEERS.

Reynolds Smoke Consumer Tested.—Forty Members of ihe Engineering Fraternity Examine the Plant at the Water-Works and Endorss the Smoke-Consuming Appliance.

An invitation was extended to the engineers of Omaha to visit the water-works on Sunday afternoon, May 14, and in response forty of Omaha's best engine-runners assembled at the lodge-rooms of the National Association at 1:30 o'clock. The party consisted of representatives of the National Association, American Order, and engineers not connected with either organization. The invitation was extended by the Reynolds Smoke-Consuming Furnace Company, for the purpose of investigating the workings of their patented principle of smoke consuming.

Owing to the recent action of the City Council in adopting a smoke-nuisance ordinance, the question is now a living one here, and all engineers are interested. The water-works are situated at Florence, five miles from Omaha, and the engineers were conducted thither in carriages, headed by an elegant tallyho coach drawn by six black horses. The ride was most delightful, and thoroughly enjoyed by the participants. Upon arrival at their destination, Captain Reynolds received his guests with a hearty handshake and cordial welcome.

Right here a brief mention of this unusually fine plant will not be out of order, as Omaha's water-works are said to be the finest in the country. The grounds encompass eighty-seven acres, including the basins, of which there are seven, each overflowing into the next, thus causing the chocolate-colored waters of the Big Muddy to bear a close resemblance to clear drinking-water by the time it has arrived at the wells, from whence it is pumped into the mains. The engine-house is a gray sandstone structure, 100 feet square, of a Greek style of architecture, with entrances on the north and south sides. Large, well-kept lawns and beautifully arranged beds of flowers tend to adorn the premises. The boiler-rooms form an L on the west of the main building, 50 by 125 feet, containing eleven vertical boilers of 225-horse power each. At the time of the visit eight boilers were in operation, fired with the cheapest Iowa slack coal, and from the stack came only a light blue vapor, with absolutely no black smoke. These boilers were generating steam for the E P. Allis low-service pumps, with steam cylinders 25x36 high pressure and 47x36 low pressure; capacity, 14,000,000 gallons each per twenty-four hours; also one E. P. Allis triple expansion high-service pump, with high-pressure cylinder 40 inches in diameter, intermediate 70 inches, low pressure 104 inches, all of 60-inch stroke; crank set at an angle of 120 degrees; capacity, 18,000,000 gallons per twenty-four hours. Thus about 1200-horse power of work was being done at the time of the visit.

This almost miraculous result was accomplished by the Reynolds Smoke-Consuming Furnace, built on the following principle: The furnace is built in front of the boiler, where space in the boiler-room permits. It is built with a fire-brick arch thirty-six inches above the grates, with another arch sprung down back of the bridge wall, thus choking the space equal to the area of the flues, allowing the gases to expand in the combustion-chamber, where the heated air commingles with them and the oxygen completes the work of combustion. It then passes through a perforated arch built of the best fire-brick. Here again the space is contracted to the area of the flues, the perforations being the thickness of the fire-brick. To the rear of the perforated arch the chamber directly underneath the boiler has a pavement slanting upward toward the end at an angle of about thirty degrees. Wings at the rear end of the boiler on each side direct the course of the heat downwards, thus giving the lower flues an equal amount of heat with the upper flues.

This elaborate plant is under the management of Captain Frank Reynolds, mechanical and consulting engineer of the American Water-Works System.

After indulging in several hours' examination of the craft, they returned to the city, well satisfied with the knowledge they had gained and equally well pleased with their entertainment

and ride. Upon arriving home a committee was appointed, consisting of Messrs. Walter B. Stark, T. J. Collins, C. Soudenburg, H. A. Seymour and G. Cahow, to draft resolutions of approbation and thanks. The following is the result of their labors:

WHEREAS, Through the courtesy of the management of the Reynolds Smoke-Consuming Furnace Company we, the engineers of the City of Omaha, have been given a most excellent opportunity to make a thorough investigation of the principles of their invention; therefore, be it

Resolved, That we fully appreciate and cordially endorse the Reynolds Smoke-Consuming Furnace as the most practical and economical that has been brought to our notice either individually or as a body.

Resolved, That the most severe tests we could apply resulted in as near a perfect combustion as could be desired by the most critical city father.

Resolved, That the hearty thanks of all present be extended to Captain Frank Reynolds, chief engineer of the Omaha Water-Works; Mr. A. B. Hunt, superintendent of the Omaha Water-Works, and Mr. M. H. Collins, secretary of the Reynolds Smoke-Consuming Furnace Company, for the delightful drive and generous hospitality while their guests on Sunday afternoon, May 14, 1893.

Resolved, That a copy of these resolutions be forwarded *The Power* and the *Weekly Stationary Engineer* for publication.

W. B. STARK,
T. J. COLLINS,
C. SOUDENBURG,
H. A. SEYMOUR,
FRANK ALEXANDER,
CHARLES E. WEEKS,
JOE WELZENBAUGH,
Committee.

TESTIMONIALS.

SOUTH OMAHA, NEBR, April 28th, 1894.

TO WHOM IT MAY CONCERN:

I have personally examined the furnaces now being used at the Omaha Water-Works, of which Mr. Frank Reynolds is the inventor, and have decided to put them in under our twenty-seven boilers, as, in my judgment, after having examined all the devices that are now in use and are offered on the market, I consider that the Reynolds Furnace is by far the most durable and economical. Yours truly,

THE CUDAHY PACKING COMPANY,
MICHAEL CUDAHY, President.

OMAHA, NEBRASKA, Dec. 9th, 1893.

REYNOLDS FURNACE COMPANY,

Gents: Replying to your inquiry as to our opinion of the qualities of your smoke-consuming furnace, which was placed in the Telephone Company building during last summer, I take pleasure in saying that it is giving good satisfaction, and is as near a perfect smoke-consumer as any I have seen. Respectfully,

C. E. YOST, President.

OMAHA, NEBRASKA, Nov. 18th, 1893.

TO WHOM IT MAY CONCERN:

After a thorough examination of the Reynolds Smoke Consumer, and having placed it in the plant of Mr. J. A. Creighton, I am satisfied it is the most practical and perfect of any yet seen, and would not hesitate to place it in any plant in preference to anything I know of.

Very respectfully,

JAMES CREIGHTON,

Ex-Chairman of Board of Public Works, Omaha, Neb.

DENVER, COLORADO, Feb. 17th, 1894.

A. B. HUNT, Esq.,

Supt. American Water-Works Co., Omaha, Nebr.

My Dear Sir:

In reply to your recent letter inquiring about the Reynolds Furnace Boiler setting placed at our works some years ago, would say:

It has been in use since 1891, and we have had no expense whatever for repairs, and it has been the most economical boiler setting we have ever known; little or no smoke coming out of the smoke-stack at any time during the use of these boilers. I can highly recommend them as the most economical and efficient boiler setting furnace on the market to-day.

Very truly yours,

D. G. THOMAS,

Supt. of the American Water-Works Co.

OMAHA, NEBRASKA, Dec. 9th, 1893.

THE REYNOLDS SMOKE-CONSUMING FURNACE CO.,

Omaha, Nebr.

Gentlemen: This company has eighteen boilers with the setting, your patent, in use five years. They are now and have been running on slack coal, with a high degree of economy and absence of smoke, and are very satisfactory in every way. Very respectfully,

ELLIS L. BIERBOWER,

Receiver.

OMAHA, NEBRASKA, Nov. 21st, 1893.

REYNOLDS FURNACE CO., Omaha, Nebr.

Gentlemen: Your favor of the 20th received. In answer to your inquiry as to how your furnaces, which your company set for us last July, are working, I desire to say that they are giving perfect satisfaction. The furnace is a fuel saver and at the same time is the most perfect device to get away with smoke that I have ever seen. Respectfully yours,

R. W. BAKER,

Supt. Bee Building.

OMAHA, NEBRASKA, Oct. 16th, 1894.

TO WHOM IT MAY CONCERN:

Having procured copies of smoke ordinances of all the cities of the United States, and having learned of the efforts made to abate the smoke nuisance in many of our prominent cities while attending the first annual meeting of the National Chiefs of Police Union at St. Louis last May, and also having perused and made comparisons of reports of scientific tests of all so-called smoke consumers, and personally examined a large number of smoke-consuming devices, I cannot but say that in my opinion the Reynolds Smoke-Consuming Furnaces are the best in this country to-day. I have seen these furnaces in operation at the water-works at Florence, Nebraska, very frequently during the last five years, and can bear witness to the fact that they are a most effectual smoke-consuming furnace

in every sense of the term. That this extensive steam plant is easily supplied with all necessary power on the commonest, dirtiest, cheapest slack coal that can be procured, and that not a dollar has been expended in repairs to the furnaces since they were first used at this plant.

The Reynolds brick furnaces are natural smoke-consumers that make the necessary steam for all purposes on a cheap grade of coal that cannot be used in ordinary furnaces.

W. S. SEAVEY,
Chief of Police.

Clipping from Sioux City (Iowa) Journal, Oct. 25, 1895, headed "A Successful Experiment":

An experiment was made at the Main street pumping station, Wednesday and Wednesday night, which proved entirely satisfactory. The Reynolds furnaces recently put in at this station are giving constantly increasing satisfaction. The economy effected in fuel saving has been fully as great as claimed, and the boiler inspector estimates that their use adds five years to the life of a boiler.

PHIL CARLIN,
Supt. Sioux City Water-Works.

A. B. HUNT, Esq. ST. LOUIS, MO., March 25, 1896.
Bee Building, Omaha, Neb.

Dear Sir: The City Hall furnace is working satisfactorily. The subcontractors on this part of the work are very highly pleased with it. They say that after it is thoroughly heated up it is impossible to make it smoke, even with malice aforethought. I hope to arrange for a complete test of this plant in the near future, and will then advise you further. Have written Captain Reynolds to the same effect.

I enclose one of our circulars, just issued, which may interest you.

Yours truly,
BRYAN & HUMPHREY,
Consulting Engineers.
By W. H. BRYAN.

A B. HUNT, Esq., OMAHA, January 25, 1897.
Omaha, Neb.

Dear Sir: In r ply to your question in regard to how we are pleased with the Reynolds furnace, would say we have had our boilers with this furnace in constant use for about four years. It has done and is doing more than you claimed for it, and is a fuel saver. We are very much pleased with it.

Yours truly,
FRANK MURPHY,
President Omaha Gas Mfg Co.

CITY OF SIOUX CITY.
C. W. FLETCHER,
Mayor.

SIOUX CITY, Iowa, August 16, 1895.

WM. H BRYAN,
St. Louis, Mo.

Dear Sir: Yours of the 13th at hand and contents noted. We have been using the Reynolds Smokeless Furnace since July 19th, at a saving of six dollars per day, and the smoke-consuming device is perfect. Formerly we used Walnut Block coal, but now use soft slack I believe it to be a great success in every way. Yours very truly,

C W. FLETCHER, Mayor.

WOODMAN
LINSEED-OIL WORKS.

OMAHA, NEB., 6–29–'95.

MR. A. B. HUNT, Care Water-Works Co., City.

Dear Sir: Replying to your inquiry of to-day, will say that the Smoke-Consumer put in by you two weeks ago is still in use at our mill, and gives entire satisfaction. We have never had occasion to make any change in it since your workmen left the job. Yours truly,

F. E. RITCHIE, Mgr.

OMAHA, NEBR., Oct. 22, 1896.

A. B HUNT, Esq , City.

Dear Sir: In reply to your inquiry of 21st inst. in regard to Reynolds furnace, will say that we have had our boilers with this furnace in constant use for three (3) years without having any trouble with arches, walls, or any part thereof. We therefore consider them durable, efficient, and a perfect smoke consumer. Any further information will be cheerfully given

We remain, yours respectfully,

(Signed) OMAHA BREWING ASSOCIATION.

P. S.—We intend to put in two new boilers this coming winter, and will put in the Reynolds furnace. OMAHA BREWING ASSOCIATION.

G. Storz, President

OMAHA STREET RAILWAY COMPANY. OMAHA, NEB., January 23, 1897.

To A B. HUNT, City.

Dear Sir: In answer to yours regarding the Reynolds Smoke Consumer, we have only the best words possible The furnaces set in our power plant are doing splendid service Far superior to anything we have ever used in any way. Respectfully,

OMAHA STREET RAILWAY CO.

W A SMITH, General Manager.

JANUARY 27, 1897.

FRANK REYNOLDS, Omaha, Neb.

Dear Sir: In answer to yours of this date, inquiring as to how we like the Reynolds smoke-consuming furnace that your company set for us three years ago, have this to say: The furnace has given perfect satisfaction in every respect It is a durable, fuel-saving device, and at the same time it is a perfect smoke consumer Yours, etc ,

JOHN B RUTH,

Manager of Standard Oil Company.

ST. LOUIS, MO., SEPT. 26, 1894.

A. B. HUNT, ESQ,

OMAHA, NEBR.

Dear Sir: Agreeably to the instructions of yourself and your associates, I recently paid two visits to Omaha and Florence, Nebr., and while there conducted a number of independent tests of the Reynolds Patent Furnace, as applied to steam boilers.

The furnaces tested were both located at the pumping stations of the American Water-Works Company. The one at Twentieth and Poppleton avenue, at Omaha, was under an ordinary horizontal tubular boiler; while the one at Florence, Nebr., was under a Reynolds Patent Vertical Boiler.

I had previously expressed my instruments and apparatus, and had given full instructions regarding the preparations necessary. Immediately on my arrival at the plant, I looked over the work and saw that my directions had been complied with. Scales and gauges had been tested; weighing and measuring tanks had been connected; flanges blanked, and pipe connections made, so that the boiler to be tested could be fed independently. The boiler and furnace had been cleaned and were in good condition for test.

THE FURNACE.

The furnace tested is the invention of Captain Frank Reynolds, Chief Engineer of the Omaha Water-Works System, and is covered by patent No. 486,167, dated November 15th, 1892. It belongs to the class known as "Fire-Brick Arch or Checker Work Furnaces," combined with the hollow walls for preheating the air. The fire-box is built entirely independent of and away from the boiler itself. The grates may be of any good pattern, but, in the present instance, were of the shaking type. Immediately after leaving the grates, the gaseous products of combustion, in passing over the bridge wall, traverse a contracted opening and are immediately deflected downward by a hanging wall. They then emerge into a combustion-chamber of liberal dimensions, the exit from which is through another contracted throat area, or a checker work of fire-brick; from this point the gases take the usual course through the boiler tubes to the chimney.

Recognizing the value of an ample supply of oxygen, properly distributed and preheated, the inventor has made use of the principle of hollow side walls. Air is admitted into the side walls at proper points, passing through channels of considerable height but limited width. These channels are separated from the furnace proper by only the linings and arches, which are always of high temperature. This construction not only absorbs to a very large extent the heat usually lost by radiation, but returns it to the furnace, one channel discharging immediately over the fire at the front end of the grate, and the other immediately behind the bridge wall at the entrance to the combustion-chamber.

On March 8th, 1882, a special committee of experts and citizens appointed by the Mayor of the City of St. Louis made a report upon the problem of smoke abatement, which is undoubtedly the most exhaustive and authoritative review of the subject that has ever been prepared with reference to the smoky coals so common in the Mississippi Valley. After reviewing the principles of combustion and the various causes of smoke, the report makes this statement:

"In view of the facts presented, it will be seen that for the complete combustion of Bituminous coal, including the separated carbon which forms the visible smoke, it is necessary that a very high temperature be constantly maintained in the fire-place and that the air introduced for the combustion of the gases and free carbon above the fuel bed be in sufficient quantity, heated, and intimately mixed with the gases. It will also appear that with the fire-place ordinarily employed, and especially when the fire is worked by the method so commonly practiced, the conditions just mentioned are rarely attained."

No better description could be given of the principles upon which the Reynolds furnace depends for its results, and we should therefore expect the most satisfactory performance.

THE BOILER.

As already stated, the boiler tested at Poppleton Avenue is of the standard horizontal tubular type, and does not differ in any way from the approved form. The fire-box, however, is independent of the boiler, being set some distance in front of it, as required by the Reynolds setting. The processes of combustion are, therefore, in no way impeded by the presence of any heat-absorbing body, such as the boiler itself, whose temperature is always much lower than that of the fire, and which as a consequence usually reduces the temperature of the fire-box much below the point necessary for the most complete combustion possible.

The boiler at Florence is of the Reynolds Vertical Type, built by the Edward P. Allis Company, Milwaukee, Wis. It does not differ, except in detail, from the ordinary vertical, internally fired boiler, so common in very small plants. It is, however, 18 feet high over all, 6' external diameter, with 124-2½" tubes, 16 feet long—only 13 feet of which, however, are available as heating surfaces, the other three feet passing through the steam space of the boiler. The standard form of construction was departed from in this case, to the extent of cutting away most of the fire-box, there being but an annular ring, 2 feet high and 5 feet in internal diameter, leaving a water space of 6" wide. It will be seen that this construction permits of the most thorough intermingling of the heated gases with the water, and that the steam should as a rule be superheated.

The boiler rests directly upon the brick-work of the furnace, immediately above the last fire throat. The details of the boiler are admirably worked out, particularly the construction for admission of feed-water and the location of the tubes.

THE TESTS.

The first series of tests were made on August 24, 25 and 27th, 1894. Some difficulty was found in getting a satisfactory capacity out of the Poppleton Avenue boiler, and an examination of the furnace, made immediately afterward, showed that the calorimeter areas through the furnace had been unduly contracted—a fault due to the ignorance or carelessness of the brick-mason who did the work. It was decided, therefore, to put the setting in proper shape and make the test over. There also appeared to be some doubt as to the accuracy of the Florence results, and it was decided to take advantage of the opportunity and repeat that test also.

The tests were conducted in close accord with the rules established by a special committee of the American Society of Mechanical Engineers, in 1894, which rules undoubtedly represent the best standard of practice.

The usual fireman handled the fires; the ordinary slack coal was used, and the boilers were operated in all respects the same as if in every-day service, except that for the purpose of the tests they were pushed somewhat beyond their ordinary working capacity. The furnaces and boilers were heated before the test began, at which time the water level, thickness and condition of fire bed, steam pressure, etc., were noted on the logs and were brought to the same condition at the close of the test.

Frequent and regular observations were taken and noted on the logs, covering the steam pressures, chimney draft, temperatures of room, chimney, feed-water, as well as upon the Barrus calorimeter, to determine the character of the steam as to dryness. Special observers looked after the coal and water-logs; independent tally records of which were also kept, to insure a check on the logs. At Poppleton Avenue, the draft was measured at the usual place in the breeching connecting the boiler with the smoke-flue. At Florence the draft was measured some 20 feet above the level of the grates. The draft here was by no means good—due probably to the fact that the same chimney is used by eight other boilers of the same size.

FUEL.

This was slack from the Cherokee (Kansas) mines. It was, however, of excellent quality, as is shown by the analysis; evidently having been properly handled and well cared for—in fact it is quite as good as the best Illinois lump coal coming regularly to the St. Louis market. At Florence, great difficulty was found in preventing clinkers in the coal from sticking to the grates and choking the fires. On one occasion this rendered an abandonment of the test necessary, and interfered to some small degree with the test herein reported, as no doubt the capacity would have been increased had not the grates become foul the last half-hour. To avoid this as much as possible, a small amount of low-grade Iowa slack, about one-quarter of the total quantity, was mixed with the Kansas coal.

RESULTS.

These are given in detail in the accompanying tabulated reports. The separate features may, however, be discussed independently.

Smoke Abatement. As this is perhaps the most important feature of the investigation, it deserves first consideration. Two smoke charts were taken, each of an hour's duration, and

under different conditions of service, and the results were worked up by means of the planimeter. On the occasion of the first test at Poppleton Avenue, August 24th, the remarkably low average of three-tenths of one per cent of smoke for the eight hours' run was secured. This is a most excellent showing, considering the fact that the boiler was being worked beyond its rated capacity, and that the slack coal was being used; in fact, there was no smoke at all except when the fires became dirty. On the second run at Poppleton Avenue, August 27th, an effort was made to push the boiler to secure greater capacity. This effort did not succeed, however, on account of the defects in construction, explained above, but the effort made increased the smoke to an average of 2.67 per cent—a quite satisfactory result nevertheless. On the occasion of the last test, reported herewith, there was a faint blue haze issuing from the chimney all day. While it was clearly noticeable near by, it could not have been seen at all at any considerable distance, and, moreover, was not of an offensive character in any way. This faint blue haze is to some extent characteristic of the Reynolds furnace, and. in my opinion, represents the most unfavorable result that will be secured from it when properly handled. In the case of the last test, it was no doubt due to the excessive amount of moisture in the fuel—over 4 per cent—and the crowding of the fires. The first test at Florence showed an average of 2.79 per cent—the most excellent result, considering the fact that the eight boilers were connected with the same chimney, and that they were being fired irregularly, a number of different doors frequently being open, and green coal charged at the same time. It will readily be seen that if each independent furnace should make a slight cloud of smoke when fired, the result would be quite a perceptible cloud when the firing of different boilers occurred together. In no case, however, was the smoke bad, and the occasional puffs were never black, and continued but a few seconds, although the boiler under test was being crowded much beyond its nominal capacity. On the last test at Florence, the smoke reached an average of 6.325 per cent. This figure is still quite satisfactory. The explanation of the increase over the previous test is that the boiler under test was being fired nearly double its rating, while the other furnaces connected to the same chimney were being run to much below their normal capacity. These adverse conditions existed to a much greater degree than on the occasion of the previous test. Observation of this and other chimneys connected with the Reynold furnaces indicate that under normal conditions the furnace is practically smokeless. No smoke was ever made when fires were being cleaned, and in this respect the Reynolds furnace differs radically from most other improved devices; in fact, the only time that smoke was visible at all was when the fires were carelessly handled, or were allowed to get dirty, and were forced considerably beyond their usual capacity.

Efficiency. This, at Poppleton Avenue, was quite good. Unfortunately, it was not possible to make a test under the same conditions with a similar boiler set with an ordinary furnace. No direct comparison can therefore be made to determine the saving in fuel or the increase in efficiency due to the Reynolds setting. I have, however, taken the trouble to look up a number of very carefully made tests on common boilers, which show an average efficiency of 52.33 per cent. These were all made on ordinary horizontal boilers, but under varying conditions, so that they may be fairly assumed to give a fair average. I should say that the figure named, however, is *better* if anything than the average common setting will give. The Poppleton Avenue efficiency of 56.64 shows a decided improvement over the average ordinary setting; and when it is remembered that slack coal is burned and that the temperatures of the chimney gases were unusually high, that the boiler was being forced far beyond its rating, and as a consequence primed somewhat, it can be readily seen that under more favorable conditions a considerably higher efficiency would be secured.

At Florence the results were even more satisfactory, the increased efficiency, however, being largely due to the improved form of boiler. The results secured compared most favorably with that of other types of boilers.

Capacity. The result of nearly 40 per cent above the rating of the Poppleton Avenue boiler is quite satisfactory. I am satisfied that with better coal this could readily have been increased to 50 per cent. A further modification of the construction will undoubtedly permit a still further increase of capacity in those cases where this feature is of special importance.

At Florence the capacity developed was even higher, being 81.47 per cent above the boilers' rating. The surprising result is shown of evaporating over 4 pounds of water from and at 212 degrees per square foot heating surface, and of developing and maintaining a horse power with but little over 8 square feet in heating surface, with a boiler composed largely of 2½" tubes. Certainly these results have no criticisms as to lack of capacity for over-work when necessary, although my investigation indicates that the setting should be constructed originally with a view of the work expected of it.

Safety. In this respect the Reynolds furnace ranks among the best. It is true that the high temperatures which necessarily accompany all intelligent and successful efforts at smoke abatement, and which are perhaps the most prominent features of the Reynolds furnace, may result disastrously if the plant is carelessly managed and the heating surfaces allowed to become foul. These, however, are abnormal conditions which may be avoided with ordinary intelligence and care, and are not to be permitted in any well-managed plant.

The furnace proper is in no way directly connected with the boiler proper, and there is no pipe-work under pressure and no complicated mechanism of any nature; in fact, the improved results following from clean heating surfaces—due to absence of soot and the uniform temperatures, due to the use of arch and checker work—should increase the safety of the boiler plants as a whole.

Method of Handling. No extraordinary degree of skill is required to secure proper results from the Reynolds furnace, although skillful and intelligent manipulation of the fires are of value here, as they are in all boiler plants, whether of the ordinary or of any improved pattern. Such instructions as are necessary can be given the ordinary fireman in a few hours, and the results will then depend upon his faithfulness and care.

Considerable time should always be given in raising steam, so that the walls may be heated gradually and uniformly. In a short time the brick-work will become white-hot, and when the gases first given off by the disintegrating mass of coal pass through the contracted throats, which are maintained at high temperature, they are thoroughly mixed and their combustion effected under the most favorable conditions. This is of course followed by some slight reduction of temperature in the arches, which, however, is immediately regained in ample time to be ready for the next firing.

Repeated observations show that only rarely were the gases passing through the last throat colored to a perceptible degree, even immediately after firing. A considerable amount of heat is thus stored in the brick-work when steam is first raised, which it may not always be possible to realize upon fully if the runs are of an intermittent character and of short duration. Conditions for high efficiency are, therefore, best met in those plants where the work is of considerable amount and practically continuous, although occasional fluctuations of the work, and even total interruptions of the service, would not seriously affect the results, if not too long-continued.

For convenience of attachment, the Reynolds furnace may be open to some criticism, in special cases. To get the best results, it should be built outside of the boiler proper and independent of it. It is unfortunately too often the case that the firing space in the boiler-room is, through faulty design, so contracted as to barely leave room for the fireman to do his work and store a limited supply of coal. In such cases the additional space required for the Reynolds furnace can be ill spared, if at all.

Captain Reynolds has adapted his furnace to these conditions also, building the entire construction under the boiler proper, and thus taking up no more space than the ordinary setting. Excellent results are said to be secured, although hardly

as good as from the standard type. The advantages of conducting the processes of combustion independent of and apart from the relatively cold heating surfaces of the boiler are so many and of such value that a strong effort should always be made to secure this type of construction, even if it necessitates a sacrifice in some other direction.

An ordinary boiler can be changed to the Reynolds setting in a week's time—even less, if absolutely necessary.

Durability. In this respect the Reynolds furnace far surpasses any construction of this type which I have ever had occasion to examine. An inspection of the working drawings from which the furnaces are built will convince the most skeptical that the brick-work is of the most substantial and lasting character. The brick-work carries nothing but its own weight, and is of ample thickness. The air spaces undoubtedly add to the life of the brick-work by carrying away the heat. In the contracted throat area, where the temperatures probably range between three and four thousand degrees Fahrenheit, the arches are constructed of fire-brick of the most refractory character, so designed and supported as to appear almost indestructible. Investigations into the actual life of the furnace show that the anticipations of the designer had been fully realized. The repairs in the course of five years have been unimportant in amount and of only nominal cost.

Cost. Where new boilers are being set, the cost is confined to that of the necessary brick-work and the special fire fronts, neither of which greatly exceeds the cost of the ordinary setting. Even when a reasonable royalty and the cost of plants and superintendence are added to the cost, this furnace should still compare favorably with any form of boiler setting approaching it in merit. The results obtained from my tests indicate that the increased fuel efficiency will pay a good interest on the cost of the work, besides the great advantages due to the comparatively smokeless chimney and ample boiler capacity.

Attempts at the solution of the smoke problem in the same general manner as is covered by Captain Reynolds' plans have frequently been made, but I do not know of a case where the principles underlying their operation have been so carefully worked out in practice. The most serious objections that have heretofore been urged against furnaces of this type have been their lack of durability and their limited capacity for over-work. Both of these criticisms seem to have been successfully and satisfactorily answered in the two plants which I have just tested.

Although the results secured are high, an inspection of the records indicates that the fires could have been handled to even better advantage. The ash analysis shows that there was considerable unburned fuel in the refuse weighed back as ash at the end of the test. Furthermore, the steam at Florence was super-

heated. Each of these features involved some consumption of fuel for which the plant received no credit in evaporation of water.

It is interesting to note the efficiency of the Florence pumping plant as a whole. Assuming that the large Allis Pumping Engine is developing a horse power with 12 pounds of water per hour (a figure probably above the true state of affairs), you are maintaining one horse power with a consumption of less than two pounds of slack coal per hour—a result I do not believe is reached, certainly not exceeded, by any of the steam plants in the Mississippi Valley, if indeed it is equaled anywhere, with fuel of this character. Respectfully submitted.

WM. H. BRYAN,
Consulting Engineer.

RESULTS OF TESTS

MADE BY WILLIAM H. BRYAN, CONSULTING ENGINEER, ST. LOUIS, MISSOURI, OF THE REYNOLDS PATENT FURNACE, AT POPPLETON AVENUE PUMPING STATION, OMAHA, NEB., TO DETERMINE ITS SMOKELESSNESS, EFFICIENCY AND CAPACITY.

Number of Designation of Test........................One
Date...................................1894, September 15th
Duration.......................................Hours, 8
Number of Boilers in operation under test..................One
Kind of Boiler..........................Horizontal Tubular

DIMENSIONS AND PROPORTIONS.

Dimensions of shell, diameter and length............66''x18 ft.
Number and length of 4'' tubes...................56 x18 ft.
Grate surface 5 ft. wide 5' long, area, sq. ft 25
Water heating surface, sq. ft..........................1276.5
Superheating surface, sq. ft..........................None
Ratio of grate surface to water heating surface, 1 to......51.06
Mean opening of damper (percentage of full opening)....100
Chimney dimensions, height and diameter.............151'x6'

AVERAGE PRESSURES.

State of weather..................................Clear
Atmosphere as per Barometer, inches................. 28.96
Steam in boiler by gauge, pounds.......................113.3
Steam in boiler, absolute, pounds......................128.0
Force of draught, inches of water..................... .70

AVERAGE TEMPERATURES.

Of external air	Deg. F.	73.8
Of boiler-room	" "	78.9
Of escaping gases entering chimney	" "	671.57
Of feed-water entering boiler	" "	157.38
Of steam in boiler	" "	346.

FUEL.

Kind of coal		Cherokee slack
Cost per ton of 2,000 pounds, delivered		$1.90
Calorific power by calorimeter, British Thermal Units, per pound		11353.
Theoretical evaporative power, from and at 212 deg. F. in pounds of water, per pound coal		11.74
Total quantity consumed	lbs.	6120.
Total ash, clinkers, and unburned coal	lbs.	919.
Proportion of ash, etc., to coal		15 per cent
Unburned coal in ash	lbs.	229.
True ash	lbs.	690.
Total combustible burned	lbs.	5201.
Mean thickness of fire	inches	3.5

RATE OF COMBUSTION.

Coal, per hour	lbs.	765.
Combustible, per hour	lbs.	650.
Coal, per sq. ft. grate surface per hour	lbs.	30.6
Combustible, per sq. ft. grate surface per hour	lbs.	26.
Coal, per sq. ft. heating surface per hour	lbs.	.599
Combustible, per sq. ft. heating surface per hour	lbs.	.509

CALORIMETERIC TESTS.

Quality of the steam (dry-steam 100)		98.85
Amount of water entrained in the steam	per cwt	1.15
Amount of superheating	Deg. F.	None

WATER.

Amount apparently evaporated	lbs.	37466.
Amount actually evaporated, corrected for quality of steam	lbs.	37040.
Factor of evaporation		1.0992
Equivalent evaporation into dry steam from and at 212 degrees F		40714.

ECONOMIC EVAPORATION.

Per pound of coal:		
Water evaporated	lbs.	6.05
Equivalent from and at 212 deg. F	lbs.	6.65
Per pound of combustible:		
Water actually evaporated	lbs.	7.12
Equivalent from and at 212 deg. F	lbs.	7.83

EVAPORATION PER HOUR.

Water actually evaporated....................lbs.	4630.
Equivalent from and at 212 deg. F............lbs.	5089.
Per square foot heating surface:	
Water actually evaporated....................lbs.	3.63
Equivalent from and at 212 deg. F............lbs.	3.99
Per square foot grate surface:	
Water actually evaporated....................lbs.	185.20
Equivalent from and at 212 deg. F ....lbs.	203.57

EFFICIENCY.

Percentage of total calorific power utilized, of efficiency..........................per cent	56.64
Water evaporated for $1.00 worth of fuel......lbs.	6370.
Cost of evaporating 1,000 lbs. of water.......cents	15.7

HORSE POWER.

Actually developed on basis of 34½ lbs water evaporated per hour from and at 212 deg. F., H. P.	147.52
Commercial rating, at 12 sq. ft. heating surface H. P.	106.38
Proportion capacity developed as of commercial rating..........................per cent	138.67
Heating surface required to develop one horse power.............................sq. ft.	8.62
Coal consumed per horse power per hour......lbs.	5.19

SMOKE RECORD.

Mean smoke production..........on a scale of 100	5.1

ANALYSIS (AVERAGE).

Coal—	
Moisture....................................per cent	4.36
Volatile matter..	28.35
Fixed carbon..	47.53
Sulphur..	4.68
Ash...	15.08
	100.00
Ashes—	
Moisture..	.46
Volatile matter..	5.34
Fixed carbon..	19.30
Ash...	74.90

RESULTS OF TESTS.

MADE BY WILLIAM H. BRYAN, CONSULTING ENGINEER, ST. LOUIS, MISSOURI, OF THE REYNOLDS PATENT FURNACE, AT FLORENCE (NEBRASKA) PUMPING STATION, TO DETERMINE ITS SMOKELESSNESS, EFFICIENCY AND CAPACITY.

Number or other Designation of Test		TWO
Date		1894, September 16th
Duration	Hours	8.05
Number of boilers in operation under test		ONE
Kind of boiler		Reynolds Vertical

DIMENSIONS AND PROPORTIONS.

Dimensions of shell, diamond and length	72"x18 ft.
Number and length of 2½" tubes	124-16
Grate surface 5 ft wide 4 ft long, area, square feet	20
Water-heating surface, square feet	1101 35
Superheating surface, square feet	243 30
Ratio of grate surface to water-heating surface, 1 to	55 07
Mean opening of damper (percentage of full opening)	100
Chimney dimensions, height and diameter	122"x8'

AVERAGE PRESSURES.

State of weather		CLOUDY
Atmosphere, as per barometer	inches	28.90
Steam in boiler, by gauge	lbs.	110.4
Steam in boiler, absolute	lbs.	125.1
Force of draught	inches of water	.40

AVERAGE TEMPERATURES

Of external air	Deg. F.	68.63
Of boiler-room	Deg. F.	84.12
Of escaping gases entering chimney	Deg. F.	565.85
Of feed-water entering boiler	Deg. F.	140.61
Of steam in boiler	Deg. F.	344.20

FUEL.

Kind of coal		Kansas and Iowa slack mixed
Cost per ton of 2,000 pounds, delivered		$1.80
Calorific power by calorimeter, British thermal units, per lb.		10900.
Theoretical evaporative power, from and at 212 deg. F. in lbs. of water, per lb coal		11.27
Total quantity consumed	lbs.	4835.
Total ash, clinkers, and unburned coal	lbs.	947.
Proportion of ash, &c., to coal		19.6 per cent
Unburned coal in ash	lbs.	98.
True ash	lbs.	849.
Total combustible burned	lbs.	3888.
Mean thickness of fire	inches	3.

RATE OF COMBUSTION.

Coal, per hour	lbs.	600.62
Combustible, per hour	lbs.	483.00
Coal, per sq. ft. grate surface per hour	lbs.	30.03
Combustible, per sq. ft. grate surface per hour	lbs.	24.15
Coal, per sq. ft. heating surface per hour	lbs.	.545
Combustible, per sq. ft. heating surface per hour	lbs.	.438

CALORIMETERIC TESTS.

Quality of the steam (dry-steam 100)	100.
Amount of water entrained in steam........per cent	NONE
Amount of superheating........Deg. F.	.81

WATER.

Amount apparently evaporated........lbs.	33126.
Amount actually evaporated (corrected for quality of steam) pounds	33126.
Factor of evaporation	1.117
Equivalent evaporation into dry-steam from and at 212 deg. F., pounds	37002.

ECONOMIC EVAPORATION.

PER POUND COAL:	
Water actually evaporated........lbs.	6.85
Equivalent from and at 212 deg. F........lbs.	7.65
PER POUND COMBUSTIBLE:	
Water actually evaporated........lbs.	8.52
Equivalent from and at 212 deg. F........lbs.	9.52

EVAPORATION PER HOUR.

Water actually evaporated........lbs.	4115.
Equivalent from and at 212 deg. F........lbs.	4596.
PER SQUARE FOOT HEATING SURFACE:	
Water actually evaporated........lbs.	3.47
Equivalent from and at 212 deg. F........lbs.	4.17
PER SQUARE FOOT GRATE SURFACE:	
Water actually evaporated........lbs.	205.75
Equivalent from and at 212 deg. F........lbs.	229.82

EFFICIENCY.

Percentage of total calorific power utilized, or efficiency	67.89 per cent
Water evaporated for $1.00 worth of coal........lbs.	7610.
Cost of evaporating 1,000 pounds of water	13.1 cent

HORSE POWER.

Actually developed on basis of 34½ pounds water evaporated per hour from and at 212 deg. F., H. P.	133.25
Commercial rating at 15 sq. ft. heating surface, H. P.	73.42
Proportion capacity developed as of commercial rating	181.47 per cent
Heating surface required to develop one horse power, sq. ft.	8.27
Coal consumed per horse power per hour........lbs.	4.51

SMOKE RECORD.

Mean smoke production........On a scale of 100	6.325

ANALYSIS (AVERAGE).

Coal –	
Moisture	4.83 per cent
Volatile matter	26.28
Fixed carbon	45.49
Sulphur	5.48
Ash	17.92
	100.00
Ashes—	
Moisture	.50
Volatile matter	2.44
Fixed carbon	7.86
Ash	89.20